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An air pollution monitoring program was initiated by the Arctic Environmental Research Station (AERS). Ambient monitoring was done throughout the winters of 76-77 and 77-78 at the Fairbanks Post Office and on the AERS roof. Indoor-outdoor monitoring was done at the new State Building during January 1979. Pollutants measured were nitric oxide (NO), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), total suspended particulates (TSP), sulfate ($SO_4^=$), nitrate (NO_3^-), lead (Pb) and carbon monoxide (CO).

High values, compared to those measured in the contiguous states, were found for NO and Pb. Most SO_2 levels were below the analyzer sensitivity of 0.004 ppm. The health effects of the measured levels of NO are not known, but Pb levels exceeded EPA standards. More monitoring for Pb is needed and, if the high concentrations are found to be area wide, then local authorities may want to consider restrictions on use of leaded gasoline during the winter months.

The garage under the new State Building with attendant air infiltration appeared to be responsible for higher indoor than outdoor CO levels.

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A STUDY OF WINTER AIR POLLUTANTS

at

FAIRBANKS, ALASKA

Harold J. Coutts

Arctic Environmental Research Station
Corvallis Environmental Research Laboratory
College, Alaska 99701

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
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FOREWORD

Effective regulatory and enforcement actions by the Environmental Protection Agency would be virtually impossible without sound scientific data on pollutants and their impact on environmental stability and human health. Responsibility for building this data base has been assigned to EPA's Office of Research and Development and its major field installations, one of which is the Corvallis Environmental Research Laboratory (CERL).

The primary mission of the Corvallis Laboratory is research on the effects of environmental pollutants on terrestrial, freshwater, and marine ecosystems; the behavior, effects and control of pollutants in lake systems; and the development of predictive models on the movement of pollutants in the biosphere. CERL's Arctic Environmental Research Station conducts research on the effects of pollutants on Arctic and sub-Arctic freshwater, marine water and terrestrial systems; and develops and demonstrates pollution control technology for cold-climate regions.

This report presents findings from several winter investigations of air pollutants in and near Fairbanks, Alaska.

Thomas A. Murphy
Director, CERL

ABSTRACT

It has been well documented for the past ten years that Fairbanks, Alaska has an air pollution problem with carbon monoxide (CO), particulates and ice fog, but there are other pollutants that have not been routinely monitored.

In addition, the theory has been raised that the low temperature and low insolation at this latitude may enhance conversion of precursory pollutants into their more toxic forms, e.g., nitric oxide into nitrogen dixide.

Consequently an air pollution monitoring program was initiated by the Arctic Environmental Research Station (AERS). Ambient monitoring was done throughout the winters of 76-77 and 77-78 at the old downtown Fairbanks Post Office and also on the AERS roof during the winter of 76-77. Indoor-outdoor monitoring was done at the new State Building during January 1979. Lead data obtained by the Fairbanks North Star Borough is also presented.

Pollutants measured during the first winter were nitric oxide (NO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), total suspended particulates (TSP), sulfate ($SO_4^=$), nitrate (NO_3^-), and lead (Pb). During the second winter, only the gaseous forms were measured. At the State Building NO, NO_2, and CO were measured.

High values, compared to those measured in the contiguous states, were found for NO and Pb. Most SO_2 levels were below the analyzer sensitivity of 0.004 ppm. The health effects of the measured levels of NO are not known, but Pb levels exceeded EPA standards. More monitoring for Pb is needed and, if the high concentrations are found to be area wide, then local authorities may want to consider restrictions on use of leaded gasoline during the winter months.

The garage under the new State Building with attendant air infiltration appeared to be responsible for higher indoor than outdoor CO levels. There was no evidence found that the natural environment hastened the transformation of NO and SO_2 to their more toxic forms.

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Jerry Fisher, Richard Joy and Barry Corell of the Fairbanks North Star Borough assisted with instrument maintenance, data analyses, loaned monitoring and test instruments, and provided the Fairbanks carbon monoxide data, the North Pole data, and the lead data at sites other than the Federal Building.

Norman Sefer of North Pole Refining permitted our use of their NO_x, O_3 calibrator.

Robert Jackson checked and calibrated the monitoring instruments.

Frank Butler and the Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Research Triangle Park supplied the High Volume filters and conducted nitrate, sulfate and lead analyses.

Kendal Adams and the Alaska Department of Buildings and the staff of the Alaska Department of Environmental Conservation provided access to and assistance in setting up monitors at the new Alaska State Building.

SECTION 1

INTRODUCTION

A major objective of this investigative program was to measure the various air pollutants and their interactions and to compare results with the present primary air quality standards.

As the urban population in Alaska has increased, there has been much concern over air pollution in what would seem to be a relatively pristine area. Air pollution becomes a serious problem when people attempt to live in urban regions in this climate. The most visible urban air pollution problem in this northern region is ice fog which occurs during the colder, dark winter months. Ice fog is composed of minute ice crystals that are produced when water vapor is released into ambient air that is too cold to hold it in solution. Interference by ice fog has reduced visibility which increased automobile accidents and limited commerce by closing airports.

The presence of other pollutants in ice fog has been acknowledged for over ten years (1). One researcher has reported that ice fog, and associated atmospheric thermal inversions,

increase the ambient levels of lead compounds and toxic gases including nitrogen and sulfur oxides, aldehydes, and halides (2). Several other investigators (3), (4), and (5) have measured levels of these pollutants in the Fairbanks area. The highest levels of carbon monoxide, a major pollutant in Fairbanks, Alaska, were not necessarily present during ice fog. Carbon monoxide, since it is emitted at ground level, is more easily trapped in surface based thermal inversions. Carbon monoxide is a known health hazard; the others are a potential health hazard. When considering nitrogen and sulfur oxides their emitted (primary) forms are nitric oxide (NO) and sulfur dioxide (SO_2). Low temperature atmospheric interaction of these primary pollutants might increase their toxicity. For example:

Over 90 percent of the nitrogen oxide (NO_x) emission is NO. In the atmosphere it slowly oxidizes at 25°C to nitrogen dioxide (NO_2). Under normal, warm conditions (>0°C) NO may be dispersed before it can be significantly converted to NO_2. The NO oxidation rate with oxygen increases as temperature decreases (6). It is therefore expected that a much larger fraction of the urban NO_x exists as NO_2 during low ambient temperatures. There also is a differential health effect. Of the two nitrogen oxides, NO_2 is reported as the more toxic (7). The possibility of higher levels of the more toxic form at low temperatures warrants investigation. That investigation is part of this report.

SO_2 air quality criteria are based upon warm temperature (lower 49 state) health effects data. SO_2 is the major precursor of sulfate ($SO_4^=$). The ambient air SO_2 to $SO_4^=$ ratio is affected by temperature. Of these two forms, $SO_4^=$ is considered to be the more toxic (8). The present SO_2 air quality standard may not be applicable to cold climates where the SO_2 to $SO_4^=$ ratio could be much different. It was planned to evaluate that ratio in this study.

In high latitude regions such as Alaska the ambient ozone (O_3) levels are expected at times to be naturally high due to stratospheric downwelling. The stratosphere contains high concentrations of O_3. O_3 level readings at Fairbanks, Alaska in 1950 showed several months during the spring when all daily values exceeded the EPA oxidant standards (9). Recent NOAA data (1974) for Barrow, Alaska shows values lower than the standard (10). To investigate this apparent discrepancy O_3 measurements were planned.

The levels of aldehydes and halides were not felt to be significant so there was no attempt to monitor them.

The in situ atmospheric forms of nitrogen and sulfur oxides were continuously monitored and correlated with other air pollutants. Continuous measurements for O_3, SO_2, NO, and NO_2 were performed with electronic instrumentation. Lead (Pb), $SO_4^=$ and nitrate (NO_3^-) were captured as par-

ticulates and determined by wet chemistry. Carbon monoxide data was furnished by the Fairbanks North Star Borough and the Alaska Department of Environmental Conservation. Pb data at sites other than the Federal building were also supplied by the Borough.

It was planned to conduct the air quality measurements daily for one full year at an urban and a rural site. The major urban site was the old Federal building in downtown Fairbanks, Alaska. Other urban sites were monitored.

The new Fairbanks, Alaska State Building has its air intake for the heating and ventilating unit (HVU) located on the roof. This is not conventional design, but is recommended to reduce the intake of automotive exhaust gases. However, the building has a parking garage as its basement. Leakage from the garage into the HVU would impair the indoor air quality. To investigate this possibility, indoor-outdoor air quality monitoring was conducted at the State Building during January 1979.

The rural site was on the West Ridge of the University of Alaska, Fairbanks, Alaska. More detail on the sampling sites is in Section 3.

The measurements were accomplished during the winters of 1976 - 77, 77 - 78 and 1979. Because the winter of 76 - 77 was unusually warm it yielded very little ice fog data.

Particulates, including ice fog, were not sampled during the second and third winters.

Most of the data was obtained during the winter because that has been the air pollution season in Fairbanks. But as the population and number of pollution sources increases, so does the potential for summer season air pollution. Therefore, the future possibility of summer time air pollution will also be discussed.

SECTION 2

SUMMARY AND RECOMMENDATIONS

This report summarizes a limited winter study of some of the less commonly monitored air pollutants in the Fairbanks, Alaska area. This investigation found some things as expected and some surprises.

It is well known that mobile sources are responsible for over 90 percent of the Fairbanks CO levels; the EPA air quality standard for which is often exceeded during the winter months. Mobile sources are also major emitters of hydrocarbons, nitrogen oxides, and lead. Therefore as expected, the Fairbanks urban area has high winter time levels of nitrogen oxides and lead.

Oxidation of nitric oxide (NO) to nitrogen dioxide (NO_2) appeared to be controlled more by the concentration of ozone (O_3) than by temperature. NO readings at the Alaskan urban site were generally higher than those in the other states. Over 80 percent of the nitrogen oxides (NO_x) was NO. the NO_x concentration was found to closely track the carbon monoxide (CO) concentration. Most probably because they both come from mobile sources.

Because of comparatively high NO readings in the urban area, the health effects of NO need to be determined to see if Fairbanks has a problem.

The few pollutant measurements performed outside urban Fairbanks indicate that the air pollution problem may be more widespread in other areas of high automobile use such as the City of North Pole, Alaska. Also, the downwind oxidation of NO to NO_2 may be of significance when considering pollutant transport. The rural air was found to be much richer in the O_3 that oxidizes the NO to NO_2. For these reasons pollutant measurements should be taken over the entire populated air basin. The Fairbanks air basin roughly corresponds to the Chena River flood plain.

The Fairbanks downtown atmospheric lead (Pb) values were found to be very high - four times the U. S. EPA air quality standard of 1.5 micrograms per cubic meter. The complete phase out of leaded gasoline in the 1980's should alleviate this problem. Meanwhile more monitoring for Pb is needed, particulary at elementary schools since children are more susceptible to its toxic effects. If high Pb concentrations are found, then local authorities may want to consider restrictions on automobile use on school grounds or restrictions on use of leaded gasoline during the winter months.

Leakage of air pollutants from a parking garage into an adjacent building can be a serious problem. This is apparently the case with the new Fairbanks State Building. In cases with such construction (adjacent garage) it is imperative that the building ventilating system be designed and operated so as to prevent intrusion of automotive exhaust gases.

The number of automobiles is rapidly increasing in this growing northern region. Despite the mobile source control efforts, there will probably be an accompanying increase in NO_x, hydrocarbon (HC), and CO emissions. NO_x and HC are precursors to photochemical (eye smarting) smog. Their increased levels may result in smog on some warm, sunny, summer days.

SECTION 3

SYSTEMS AND PROCEDURES

SITES AND SETUPS

Two sites in the Fairbanks air shed were initially chosen for locating the monitoring equipment. The more polluted urban site was the Fairbanks station of record; where for several years, the Fairbanks North Star Borough has monitored ambient carbon monoxide (CO) concentrations. This station is at the old Fairbanks Post Office between 2nd and 3rd streets on Cushman Street. At this site EPA data could be directly correlated with Borough CO because all analyzers were sampling the same air parcel. The more rural site was located on the West Ridge, University of Alaska, Fairbanks, Alaska. Each site was felt to be representative for its area. Indoor-outdoor air quality was monitored at the new Fairbanks State of Alaska Building which is located on Barnette Street between 7th and 8th Avenues. All sites are located on Figure 1.

URBAN SITE (FAIRBANKS POST OFFICE)

From November 8, 1976 to March 12, 1977 two 6.4 mm (0.25 in) diameter teflon sample inlet tubes were routed from

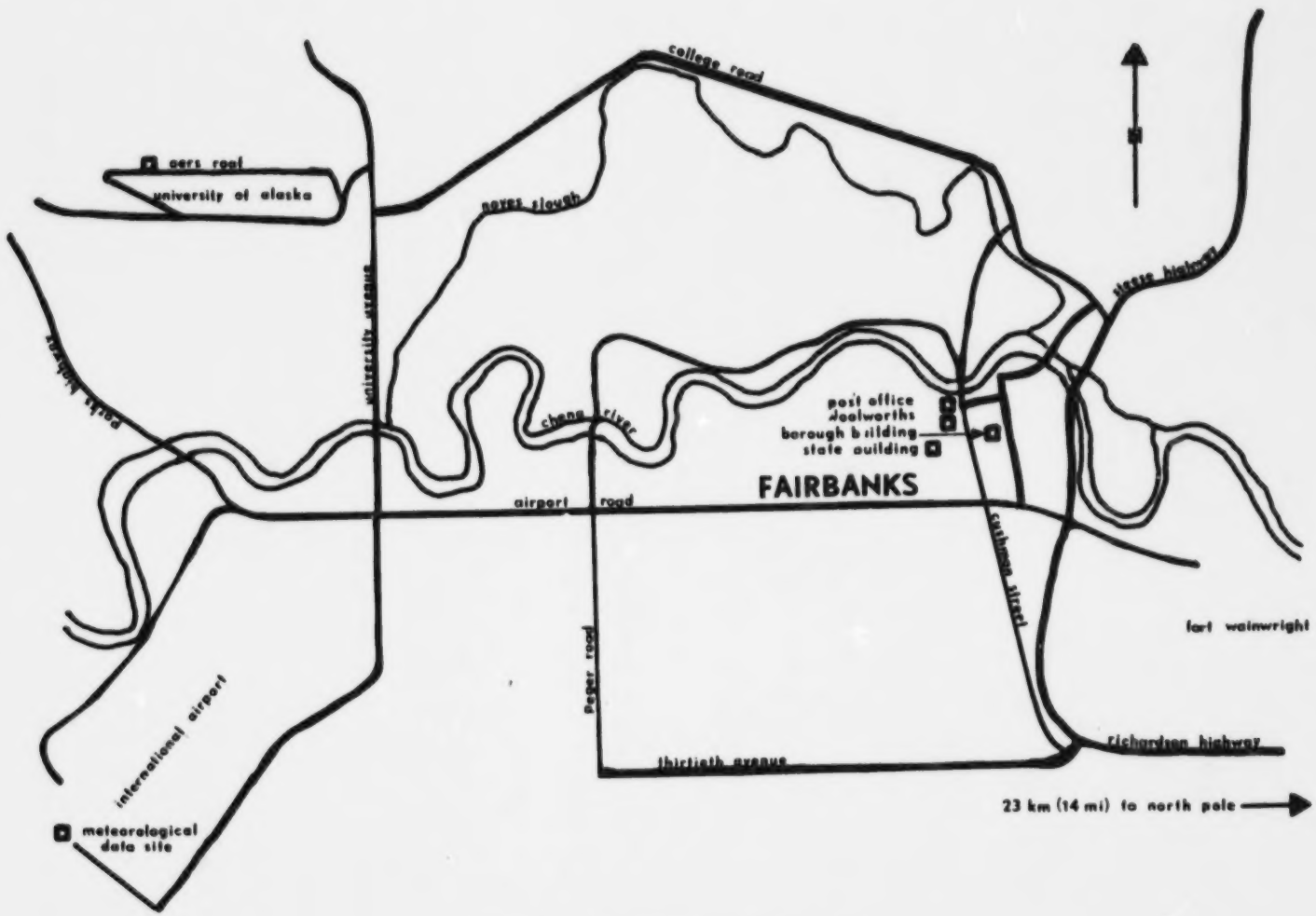

Figure 1. Fairbanks Monitoring Sites

3 m (9.5 ft) above the sidewalk and 1 m (3 ft) out from the front of the post office through a window into the basement monitoring room. The nitrogen oxide (NO_x) and sulfur dioxide (SO_2) instruments shared one of the 11.2 m (36.8 ft) long by 6.4 mm (0.25 in) teflon tubes which had a tee fitting about 2 m (6 ft) from the NO_x analyzer. From the tee, a 3.2 mm (0.125 in) teflon tube side arm ran to the SO_2 instrument. The other 6.4 mm (0.25 in) teflon tube sample line, which was 9 m (3 ft) long, ran to the ozone (O_3) monitor. One high volume particulate sampler was located adjacent to the inlet ends of the sample tubes.

All air quality monitoring instruments were shut off from March 12, 1977 to April 7, 1977. During that time the sample inlet tubing to each instrument was shortened. It was felt that these long sample lines were absorbing - adsorbing some of the NO_x before it reached the analyzer. This line loss was estimated at 25 percent using nitric oxide (NO) span gas. The long lines were replaced by a 3.1 m (10 ft) length of 7.5 cm (3 in) diameter poly vinyl chloride (PVC) sewer pipe running through the window.

Slipstreams to each instrument were tapped into the PVC pipe, 2.0 m (6.5 ft) from the inlet (window) end. The tap to the NO_x instrument was 1.5 m (4.9 ft) of 6.4 mm (0.25 in) teflon tubing. The 3.2 mm (0.125 in) teflon tubing tap to the SO_2 analyzer was 1.1 m (3.5 ft) long. And the

6.4 mm (0.25 in) teflon tubing tap to the O_3 monitor was 0.94 m (3.1 ft) long.

The inlet end of the 7.5 cm PVC pipe was about 1 m (3 ft) above sidewalk level and 0.2 m (0.6 ft) out toward Cushman Street from the post office wall. A small "muffin" fan was attached to the inside (discharge) end of this pipe to draw a fresh sample. It was initially intended that the air stream be laminar flow to reduce contamination from the PVC pipe walls. But warm air rising to the top of the post office building created such a draw through the pipe that there was turbulent flow even without the fan running.

RURAL SITE (ROOF OF ARCTIC ENVIRONMENTAL RESEARCH STATION (AERS))

The instruments for gaseous monitoring at this site were set up in the penthouse on top of the AERS building. The AERS building is located on the south rim of the west ridge of the University of Alaska campus. More specifically, the site is located in Universal Transverse Mercator Zone 6, 459780 meter Easting coordinate and 7193430 meter Northing coordinate.

The sample inlets were 13.3 m (43.5 ft) above sidewalk level. Two 6.4 mm (0.25 in) teflon tubes were run from the instruments through the skylight adjacent to the high volume sampler inlet, 1.0 m (3.3 ft) above the penthouse roof. One

of the tubes 5.3 m (17 ft) long ran to the O_3 monitor. The tube for the SO_2 and NO_x analyzers was teed at the SO_2 analyzer. Its total length was 6.6 m (22 ft) to the NO_x analyzer and 5.3 m (17 ft) via the tee to the SO_2 analyzer.

INDOOR - OUTDOOR SITE (STATE BUILDING)

The indoor air was sampled at the heating ventilating unit (HVU) duct which supplied air to the interior of all rooms. The duct carried about two thirds of the total air supplied to all rooms. From January 16 through January 25, 1979, a 6.4 mm (0.25 in) diameter teflon tube about 0.6 m (2 ft) long was routed from the HVU duct (at the first floor level) to the analysers. One tube to the NO analyser and the other to a CO analyser.

The outdoor ambient air sampling was at the same location as the Alaska Department of Environmental Conservation CO monitor. From January 16 to January 25, 1979, a 6.4 mm (0.25 in) diameter teflon sample inlet tube about 4 m (13 ft) long was routed from a point about 4.7 m (15.5 ft) above the sidewalk and 1 m (3 ft) out from the exterior wall, through the wall into the northeast corner monitoring room to a NO_x monitor.

OTHER SITES

Some of the data that was obtained from the North Star Borough, Department of Environmental Services was taken at several different sites. For particulate lead data they were:

1. On the roof of the Borough building approximately 6 m (20 ft) above street level. The Borough building is located between 4th and 5th streets near Lacy Street.

2. On Woolworth's roof approximately 5 m (15 ft) above Cushman Street. That store is located between 3rd and 4th streets on Cushman Street.

3. On the North Pole elementary school roof approximately 3.7 m (12 ft) above ground. The school is the corner of 4th avenue and Snowman Lane near the fire house.

The gaseous data for North Pole was taken at the water supply plant which is just across Snowman Lane from the fire station.

Meteorological data were obtained from the national weather service station at the Fairbanks International Airport. That station is 7.9 km (4.9 mi) southwest of the urban site and 5.2 km (3.2 mi) south of the rural site. The urban site was 6 m (18 ft) above the airport elevation. The rural site was 70 m (230 ft) above airport elevation but was seldom

above the atmospheric inversions which often top out at 200 to 2000 m (600 to 6000 ft) above Fairbanks.

GASES

Concentrations of the following gases were continuously measured by electronic instruments attached to chart recorders.

NO-NO_x

A Monitor Labs Inc. model 8440 analyzer was used for measuring NO and NO_x concentrations in the atmosphere. The analyzer measured the light given off by the chemilumenescent reaction of NO with O_3 to determine the NO concentration. The NO_x (which is NO + NO_2) concentration was determined by first quantitatively reducing, over a molybdenum catalyst, the NO_2 to NO. The total NO was then measured by the above chemilumenescent reaction. The NO_2 concentration was reported by electronically substracting NO from NO_x.

During the first winter, calibration was accomplished using a Monitor Labs model 8500 calibrator as a dilution source and NO in nitrogen (N_2) span gas which was verified against a National Bureau of Standards reference. The first calibration was on February 3, 1977. Later calibrations the first winter were not on any set schedule due to limited access to the calibrator. However, four more calibrations were conducted.

A Bendix model 8861DA calibration system was used as the dilution source during the second and third winter and calibration was performed at least twice a month. Zero checks were performed daily Monday through Friday during all winters.

$\underline{SO_2}$

A Meloy Laboratories Inc. Model SA 185-2A analyzer was used to determine ambient sulfur dioxide (SO_2) concentration by the Flame Photometric Detection technique. This technique involves measuring the intensity of the light emitted by the sulfur species as it passes through a hydrogen flame. Detection specificity for SO_2 is attained by use of a 394 nanometer narrow band pass filter and a hydrogen sulfide scrubber. Calibration was performed weekly with a Meloy Model CS10-2, SO_2 permeation tube calibration source.

$\underline{O_3}$

Ozone (O_3) was measured with a Dasibi Model 1003-AH O_3 monitor, which employs the principle of ultraviolet (UV) absorption.

The monitor's response was checked by the Bendix 8861DA calibration system which has a built-in O_3 generator. The O_3 generator was calibrated by gas phase titration. Gas phase titration is the use of the quantative reaction:

$NO + O_3 \rightarrow O_2 + NO_2$ to measure the O_3 concentration. The drop in NO concentration (as measured by the NO monitor) exactly equals the O_3 concentration generated by the Bendix calibrator.

CO

The CO data at the old Federal Building were obtained by the Fairbanks North Star Borough, Department of Environmental Services (DES) with a Beckman model 865 non-dispersive infrared (NDIR) analyzer. The outdoor CO values at the new State Building were obtained by the Alaska Department of Environmental Conservation (ADEC) with a Beckman model 866 NDIR analyser. Both environmental departments (DES and ADEC) zeroed and spanned their NDIR analysers daily. The indoor CO values at the State Building were obtained with an Ecolyzer Model #7000. The Ecolyzer was spanned (checked and adjusted) with 50 ppm CO span gas at about 0900 and 1600 daily.

PARTICULATES

Total suspended particulates (TSP) were measured by use of a General Metal Works, Inc., high volume air sampler (Hi Vol) which is essentially a vacuum cleaner motor and blower with a 20 X 25 cm (8 X 10 in) glass fiber filter mounted on its inlet. The Hi Vol's outlet was an orifice for flow measurement.

Sulfate ($SO_4^=$), Nitrate (NO_3^-), and Lead (Pb) were determined by leaching them from the filter surface. $SO_4^=$ was determined by the Automated Chloranilate method (11). NO_3^- was determined by the Cadmium Reduction - Diazo coupling method (11); Pb was determined by the Atomic Absorption method (11).

MEASUREMENT ACCURACY

When sampling air at one location, it is very difficult to extrapolate the data to say, this is representative of the air people are actually breathing. The sample inlets at the urban site (Fairbanks Post Office) were, until March 1977, located 3 m (9.5 ft) above sidewalk level, well above the location of most human nostrils. Also, the inlet was approximately 3 m (9 ft) in (toward the post office) from the street curb. On April 6, 1977 the sample inlet was lowered to 1 m (3 ft) above sidewalk level. At the new State Building the outdoor sample inlet was 4.7 m (15.5 ft) above the sidewalk and 8.2 m (27 ft) in from the street curb. In all cases pedestrian traffic was between the sampler inlet and the curb. These factors indicate that people on the sidewalks were probably breathing air more contaminated with auto exhaust than that sampled.

An error analysis for some of the various measuring uncertainties follows.

NO - NO_x

The NO span gas concentration was verified against a standard reference material related to a National Bureau of Standards standard. Maximum probable error $\pm$1 percent.

The accuracy and/or precision of the Bendix calibrator was $\pm$5 percent It was initially calibrated and later rechecked by timed water displacement in a volumetric flask.

There was considerable span drift (drop in response) on the NO - NO_x analyzer during the first winter. Its first check with span gas showed that it was only indicating about 30 percent of the actual NO and NO_x concentrations. During those times when the instrument response was that low the data were not taken off the chart record.

In the second winter period the NO - NO_x analyzer was calibrated weekly, so the calibration error was never more than 5 percent. Three to six hours were required for each span during which time data was not recorded. Quite often even at full gain the NO - NO_x analyzer couldn't indicate the span gas strength although its response was always proportional. Therefore, span curves of actual NO concentration vs instrument response were utilized to correct data. The maximum drop in response amounted to 15 percent during January 1979. Checks indicated that as much as 25 percent of the NO span gas was depleted in the long inlet

line used before March 1977. So the analyzer was calibrated through this line which allowed the span curve to account for this loss. The analyzer detection limit is 0.002 parts per million (ppm) NO, NO_x or NO_2. Considering the author's feel for instrument precision and all the above inaccuracies, the maximum probable error dropped from ±40 percent for the first winter to ±20 percent for the second and third winter.

$\underline{SO_2}$

The Meloy SO_2 analyzer had a manufacturer's specified sensitivity of 0.004 ppm and a precision of 0.005 ppm. All of the readings were at or below this level, so the estimated accuracy is ±50 percent or 0.004 ppm, which ever is greater.

$\underline{O_3}$

The manufacturer's specified sensitivity for the O_3 monitor was 0.001 ppm. It was not calibrated during the first winter, but gas phase titration the second winter showed 100 percent response. Therefore, the only error is O_3 loss in the inlet lines. Since O_3 is a very unstable gas, the error is estimated to be as high as 50 percent during the first winter (with long inlet lines); down to 10 percent during the second winter with the shorter line.

CO

The error for the CO measurement with the NDIR analysers is low because they are stable instruments and the span gas strength was easily verified and could be used at full strength. Also, CO is a chemically non-reactive gas and as such is not affected by dirty or long inlet lines. The error for NDIR CO measurement is expected to be less than 10 percent. The Ecolyzer was subject to considerable drift, so its measurement accuracy is believed to be only within 2 ppm CO.

Particulates

Accuracy with the High Volume sampler is hard to estimate because of flow measurement, recycling, and semi volatile particulates. Flow calibration and measurement is estimated to be within $\pm$ 15 percent. High Volume samplers tend to resample some of the air they have just exhausted. That amount has not been quantified, but it is assumed to be in the order of 15 percent. Volatiles such as heavy hydrocarbons (oily soot) on the filters would partially evaporate in a dessicator before weighing and cause a lowering of the readings. Filter clogging with ice fog particles was not a problem because the winter of 76-77 was too warm for ice fog.

In summation, many of the particulates, $SO_4^=$, NO_3^-, and Pb values may be from 30 percent low to zero percent high.

A chronological summary of the estimated maximum probable errors is listed in Table 1. The actual errors are unknown. Therefore, the table is quite subjective. But the estimates are felt to be conservative. Easier access to the calibration equipment during the second and third winter greatly decreased the analytical errors for NO-NO_x and O_3. The errors for other sites is expected to be: $\pm$20 percent for NO-NO_x, $\pm$10 percent for O_3, and -30 +0 percent for all particulates.

TABLE 1

CHRONOLOGICAL ESTIMATE OF MAXIMUM PROBABLE ERRORS

DATE	SITE	$NO-NO_x$	O_3	SO_2	PARTICULATE (TSP), NO_3^-, $SO_4^=$, Pb
1976					
NOV	Urban	±40%	-20%	-	-30% +0%
	Rural	±40%	-25%	-	-30% +0%
DEC	Urban	±40%	-30%	-	-30% +0%
	Rural	±40%	-40%	-	-30% +0%
1977					
JAN	Urban	±40%	-50%	±0.004 ppm	-30% +0%
	Rural	±40%	-50%	±0.004 ppm	-30% +0%
FEB	Urban	±40%	-50% OR ±0.001 ppm	±0.004 ppm	-30% +0%
	Rural	±40%	-50%	±0.004 ppm	-30% +0%
MAR	Urban	±40%	-50%	-	-30% +0%
	Rural	±40%	-50%	±0.004 ppm	-30% +0%
APR	Urban	±40%	±20%	-	-30% +0%
	Rural	±40%	-50%	±0.004 ppm	-30% +0%
MAY	Urban	±40%	±20%	±0.004 ppm	-30% +0%
	Rural	±40%	-50%	±0.004 ppm	-30% +0%
SEPT	Urban	±30%	±10%	-	-
OCT	Urban	±25%	±10%	-	-
NOV	Urban	±25%	±15%	±0.004 ppm	-
DEC	Urban	±25%	±15%	±0.004 ppm	-
1978					
JAN	Urban	±20%	±10%	±0.004 ppm	-
FEB	Urban	±20%	±10%	±0.004 ppm	-
1979					
JAN	Outdoor	±20%	-	-	-
	Indoor	±20%	-	-	-

Note: A negative percentage means the value may be that percentage low.

SECTION 4

POLLUTANT SOURCES AND DISPERSION

The two important elements that determine air pollution are emission sources and dispersion. The sources, usually combustion exhaust gases, contain the pollutants in high concentrations. After emission, the pollutants are diluted by dispersion. Atmospheric dispersion equations are used to estimate the concentration of a particular pollutant at a given distance from any source under various meteorological conditions.

SOURCES

When discussing the Fairbanks air pollution problem, the sources can be broken down into two general types: mobile and stationary. The mobile sources are automobiles and trucks. Their gasoline engines are the major sources of carbon monoxide (CO), nitrogen oxides (NO_x), lead (Pb), and ice fog in the Fairbanks air. Also, a considerable fraction of the total suspended particles comes from dust entrainment by traffic on sanded streets.

In gasoline engines the CO is a result of incomplete combustion. Gasoline engines operate at such a low air to fuel ratio that there is not enough oxygen (O_2) to completely oxidize the carbon in the gasoline to carbon dioxide (CO_2).

NO_x will be used as the general formula for mixtures of nitric oxide (NO) plus nitrogen dioxide (NO_2). NO is the major component of NO_x from combustion processes. It is created by the high temperature combination of atmospheric nitrogen (N_2) and O_2. The NO is then oxidized to NO_2; slowly by atmospheric O_2, or rapidly by ozone (O_3). Automotive lead (Pb) emissions are released because of leaded gasoline. Water vapor for ice fog formation is created when the hydrogen in the hydrocarbon fuel (gasoline or diesel oil) is burned. Mobile sources are usually cited by the motoring public as being the major source of ice fog.

Stationary source emissions are mainly flue gases from power and heating plants. These flue gases are rich in NO_x, sulfur dioxide (SO_2), total suspended particles (TSP), and water vapor (ice fog).

Home heating units burning distillate oils are not a significant source of SO_2 because the local fuel oil contains less than 0.02 percent sulfur.

In comparison to the home heating furnaces and mobile sources, the power plant flue gases are emitted with such

a plume height that their gaseous emissions are usually well diluted before reaching ground level. The sulfur content of the Healy, Alaska coals is quite low, around 0.2 percent, which means that the impact of the Alaskan coal fired power plants is nowhere near as great as if they were to burn eastern United States coals with greater than 1 percent sulfur.

The coal fired power plants are significant sources of the total suspended particles which settle around and downwind of each power plant. The fly ash concentration is most evident on the surface of old snow near the power plants.

The present stoker fired power plants have no flue gas fly ash removal devices such as scrubbers, electrostatic precipitators or bag houses. For gross fly ash control they use a sedimentation chamber and multicyclones, a major purpose of which is to prevent downstream equipment such as induced draft fans from being severely eroded by the fly ash. However, when properly operated the stoker fired power plants are usually able to meet the Alaska state (1977) air quality emission regulations.

Heating and power plants are significant sources of ice fog, but because of high plume height, the ice fog from power plant stack gases does not always contribute to the Fairbanks ground level visibility problem. Ice fog from their cooling waters is more often a problem.

Ozone (O_3) is not emitted directly into the atmosphere from any particular pollution source. It comes from two sources (1) occasional down welling to terrestrial levels from a naturally occurring O_3 rich layer in the stratosphere, and (2) a complex chain of photochemical reactions initiated when hydrocarbon (HC) and NO_x emissions are exposed to sunlight.

DISPERSION

For estimating atmospheric dispersion the method of Pasquill with Gifford's conversion is recommended by EPA (12). It is used to estimate ground level concentration of a gaseous pollutant from a remote source. It assumes the plume dispersion is defined by Gaussian distributions. A major problem with this method is that during arctic winters the lower atmosphere is at times more stable than any of Gifford's stability categories. The steep but shallow winter temperature inversions that exist over the Fairbanks area usually make the Pasquill-Gifford estimates unreliable.

Typical temperature inversions over Fairbanks usually begin at ground level (surface based) and terminate at less than 500 m (1500 ft). However, normal adiabatic lapse rates may not be reached until 1 to 2 km (3000 to 6000 ft) above ground level. An inversion gradient of 1°C per meter in the lowest seven meters has been measured at the Fairbanks air-

port. However, inversion strengths of 5 to 50°C per 100 meters at the airport are much more common. For the past four years the average surface based inversion strength was 8°C per 100 meters during times when the downtown post office (urban site) 8 hour maximum CO average was 15 ppm or greater. Temperature inversions measured by the Weather Service were found to exist in over 50 percent of the surroundings during the winter months. Without these persistant winter inversions, Fairbanks would not have an air pollution problem caused by exhaust gases. However, air pollution caused by particulates could still be a problem.

SECTION 5

AMBIENT LEVELS

DATA LISTING

For the first two winters the ambient levels of the gaseous components were integrated from the data strip chart records to calculate a daily one hour highest value and a 24 hour (nominal) daily average. The particulates were listed as 24 hour daily averages. The February 1977 daily data for the urban (Fairbanks Post Office) and the rural site (AERS roof) are listed in Tables 2 and 3. All monthly averages are listed in Tables 4 and 5. February contains some of the highest pollutant levels recorded for the winter of 1976 - 77.

GASES

NO_x is the arithmatic sum of NO (nitric oxide) and NO_2 (nitrogen dioxide). For the urban data (Tables 2, 4, and 5), notice that usually less than 20 percent of the NO is oxidized to NO_2. This is especially true when the $NO_x \geq 0.2$ ppm. The rural NO (Tables 3 and 4) is approximately 50 percent oxidized to NO_2. The reason for this difference will be discussed under reactions in this sec-

TABLE 2

URBAN SITES AIR QUALITY DATA. FEBRUARY 1977

	Fairbanks, AK												Northpole, AK		
	$\underline{NO_x}$ pphm		$\underline{NO_2}$ pphm		$\underline{NO_3^-}$ µg/m³	$\underline{O_3}$ ppb		$\underline{CO}$ ppm		$\underline{SO_4^=}$ µg/m³	TSP µg/m³	Inversion Strength at Airport	$\underline{NO_x}$ pphm	$\underline{CO}$ ppm	
	24 hr ave.	1 hr high	24 hr ave.	1 hr high	24 hr ave.	24 hr ave.	1 hr high	8 hr high	24 hr ave.	24 hr ave.	24 hr ave.	°C/m	24 hr ave.	8 hr high	24 hr ave.
Column															
Date	(1)		(2)		(3)	(4)		(5)		(6)	(7)	(8)	(9)	(10)	
1	<5	---	---	---	0.3	8	18	5	3	8.9	48	snow	---	---	---
2	~5	11	---	---	1.7	1	3	6	3	6.1	60	snow	---	---	---
3	---	---	---	---	---	---	---	7	5	---	---	13/1100	---	---	---
4	25	70	3	4	1.9	---	---	18	9	9.4	96	7.5/75	---	---	---
5	18	52	1	1	---	---	---	10	6	---	---	7.9/33	---	---	---
6	38	80	3	---	---	---	---	17	11	---	---	9.8/23	---	---	---
7	32	67	2	---	2.6	1	5	15	11	5.8	79	11/54	---	---	---
8	31	95	5	---	2.2	2	8	17	11	5.8	77	12/44	---	9	6
9	19	80	3	---	1.7	2	10	15	8	5.3	57	9.8/61	13	8	2
10	---	---	---	---	3.8	---	---	15	9	5.8	82	2.6/25	24	8	4
11	26	74	4	---	3.2	1	5	15	11	6.3	95	12/36	32	9	5
12	12	30	3	---	---	1	2	13	8	---	---	8.8/66	16	8	2
13	8	23	---	---	---	<1	2	9	6	---	---	7.9/52	7	8	4
14	22	54	5	6	1.3	1	2	15	9	5.6	62	1.4/8	11	7	2
15	>30	>100	---	---	2.5	---	---	28	13	5.2	88	3.9/33	32	11	5
16	11	34	---	2	2.4	---	---	9	7	5.7	76	7.3/7	21	8	2
17	29	106	2	---	3.4	---	---	16	11	5.9	110	5.3/35	25	4	3
18	13	76	---	1	1.5	---	---	22	10	4.6	58	14/77	8	4	1
19	5	23	1	0	---	---	---	5	4	---	---	6.1/74	6	1	1
20	13	120	---	---	---	---	---	13	8	---	---	10/80	7	2	1
21	31	140	---	---	---	---	---	17	10	---	---	3.6/101	10	5	4
22	8	31	0	0	0.4	---	---	14	6	5.4	32	10/52	8	5	1
23	21	57	1	---	0.7	---	---	6	4	6.2	42	9/1000	11	4	1
24	51	180	---	---	1.4	---	---	20	12	5.6	74	5.2/26	11	4	2
25	13	44	0	---	1.0	---	---	17	4	5.9	41	9/86	8	4	1
26	8	25	2	2	---	---	---	5	3	---	---	2.9/90	6	1	1
27	8	45	---	---	---	---	---	4	2	---	---	---	11	1	0
28	11	38	---	0	1.0	---	---	7	5	5.7	53	4.7/69	7	1	1

NOTE: A tabulated value of zero (0) for the following gases means a value less than listed below:

NO, NO_2 - 0.002 ppm - 0.2 pphm - 2 ppb
O_3 - 0.001 ppm - 1 ppb
SO_2 - 0.004 ppm - 0.4 pphm - 4 ppb

ppm - parts per million
pphm - parts per hundred million
ppb - parts per billion
µg/m³ - micrograms per cubic meter at 76 cm of H_g and 25°C

TABLE 3

RURAL SITE AIR QUALITY DATA. FEBRUARY 1977

	NO ppb		NO_2 ppb		NO_3^- µg/m³	O_3 ppb		$SO_4^=$ µg/m³	SO_2 pphm		TSP µg/m³
	24 hr ave.	1 hr high	24 hr ave.	1 hr high	24 hr ave.	24 hr ave.	1 hr high	24 hr ave.	24 hr ave.	1 hr high	24 hr ave.
Column	(1)		(2)		(3)	(4)		(5)	(6)		(7)
Date											
1	---	---	---	---	0.2	---	---	2.2	0	0	7
2	---	---	---	---	---	---	---	---	0	0	---
3	---	---	---	---	0.5	14	42	1.3	0	0	8
4	---	---	---	---	---	32	45	---	0	0	---
5	---	---	---	---	---	41	49	---	0	0	---
6	---	---	---	---	---	36	45	---	0	0	---
7	---	---	---	---	0.6	37	52	1.8	0	0	7
8	15	64	10	29	---	39	48	---	0	0	---
9	37	86	12	36	---	11	33	---	0	0	---
10	>27	>100	14	68	---	27	41	---	0	0.5	---
11	>35	>100	>16	---	---	28	47	---	0	1.0	---
12	22	>100	12	>41	---	36	47	---	0	0	---
13	1	>1	0	0	---	33	52	---	0	0	---
14	3	70	7	30	---	42	48	---	0	0	---
15	42	106	23	41	---	16	49	---	0	0.5	---
16	68	310	28	90	1.1	23	42	2.7	0	0	15
17	15	130	11	65	---	42	49	---	0	0	---
18	9	70	---	70	---	45	49	---	0	0	---
19	5	25	---	25	---	42	47	---	0	0	---
20	0	0	---	---	---	46	51	---	0	0	---
21	8	70	3	20	---	39	45	---	0	0	---
22	---	---	---	---	0.5	---	---	1.2	0	0	8
23	---	---	---	---	---	37	44	---	0	0	---
24	---	---	---	---	---	39	48	---	0	0	---
25	---	---	---	---	---	37	45	---	0	0	---
26	---	---	---	---	---	33	44	---	0	0	---
27	---	---	---	---	---	35	47	---	0	0	---
28	---	---	---	---	0.4	43	49	1.4	0	0	7

NOTE: A tabulated value of zero (0) for the following gases means a value less than listed below:

NO, NO_2 - 0.002 ppm - 0.2 pphm - 3 ppb
O_3 - 0.001 ppm - 1 ppb
SO_2 - 0.004 ppm - 0.4 pphm - 4 ppb

ppm - parts per million
pphm - parts per hundred million
ppb - parts per billion
µg/m³ - micorgram per cubic meter at 76 cm of H_g and 25°C

TABLE 4

FIRST WINTER
FAIRBANKS AREA MONTHLY AVERAGE VALUES OF AIR POLLUTANTS

Location Sample (Site)	NO 24 hr	NO 1 hr	NO_2 24 hr	NO_2 1 hr	O_3 24 hr	O_3 1 hr	SO_2 24 hr	SO_2 1 hr	NO_3^- 24 hr	$SO_4^=$ 24 hr	TSP 24 hr	Pb 24 hr	% of TSP That Is Pb
	(All gases are in parts per million)								(All solids are in milligrams per cubic meter)				
1976													
Nov Rural									0.6	2.3	16	0.25	1.7
Urban	0.17	0.43	0.04	0.08	0.005	0.014	-	-	1.2	6.9	210	5.8	3.5
Ratio U/R									2	3	13	23	
Dec Rural	0.002	0.043	0.023	0.081	0.004	0.004	-	-	0.3	1.9	7	0.11	2.0
Urban	0.21	0.46	0.06	0.09	0.008	0.019	-	-	1.1	7.3	115	6.0	5.0
Ratio U/R	18	11	3	1	2	5			4	4	16	55	
1977													
Jan Rural	0.007	0.028	0.010	0.030	0.011	0.019	0.00	0.00	0.3	1.7	8	0.12	1.8
Urban	0.15	0.34	0.039	0.079	0.007	0.016	-	-	1.5	8.5	90	6.0	6.5
Ratio U/R	21	12	4	3	0.6	0.8	-	-	5	5	11	50	
Feb Rural	0.01	0.055	0.01	0.033	0.034	0.046	0.00	0.00	0.6	1.8	9	0.18	2.2
Urban	0.18	0.65	0.01	0.01	0.002	0.006	-	-	1.8	6.1	68	4.3	6.1
Ratio U/R	18	12	1	0.3	0.06	0.1	-	-	3	3	8	24	
Mar Rural	0.003	0.021	0.017	0.049	0.037	0.049	0.00	0.00	0.6	2.2	18	0.19	1.4
Urban	0.15	0.38	0	0	0.004	0.008	-	-	1.1	4.1	53	2.3	4.3
Ratio U/R	50	18	0	0	0.1	0.2	-	-	2	2	3	12	
Apr Rural	0.004	0.013	0.003	0.011	0.032	0.041	0.00	0.00	0.4	2.1	35		
Urban	0.11	0.29	0	0	0.010	0.021	-	-	0.6	3.8	500		
Ratio U/R	28	22	0	0	0.3	0.5	-	-	1.5	2	14		
May Rural	0.005	0.019	0.004	0.026	0.014	0.050	0.00	0.00	0.1	1.4	42		
Urban	0.02	0.06	0.01	0.01	0.015	0.025	-	-	0.3	2.4	300		
Ratio U/R	4	3	0	0	1	0.5	-	-	3	2	7		

A tabulated value of zero (0) for the following cases means a value less than that listed below:

NO, NO_2 - 0.002 ppm

O_3 - 0.001 ppm

SO_2 - 0.004 ppm

TABLE 5

SECOND WINTER
FAIRBANKS URBAN SITE MONTHLY AVERAGE VALUES OF AIR POLLUTANTS

	NO		NO_2		O_3		SO_2		Ratio CO/NO_x		Correlation Coefficient	
	24 hr	1 hr	24 hr	1 hr	24 hr	1 hr	24 hr	1 hr	24 hr	1 hr high	24 hr	1 hr high
1977												
Sept	0.081	0.25	0.021	0.045	0.007	0.018	---	---	-130	-140	-0.40	-0.22
Oct	0.09	0.31	0.019	0.030	0.007	0.014	---	---	45	56	0.69	0.55
Nov	0.19	0.41	0.032	0.044	0.008	0.018	0.0	0.01	82	34	0.16	0.69
Dec	0.20	0.51	0.024	0.033	0.010	0.019	0.007	0.014	24	30	0.85	0.30
1978												
Jan	0.29	0.69	0.031	0.045	0.011	0.021	0.00	0.00	29	30	0.62	0.61
Feb	0.20	0.51	0.035	0.067	0.013	0.025	0.00	0.00	21	24	0.88	0.71
								AVERAGE	34	34	0.69	0.67

A zero (0) value for SO_2 means <0.004 ppm

tion. Also note that the urban monthly average NO_x is about 10 times that measured for the rural site. The maximum one hour high NO values measured in Fairbanks rival those measured in Los Angeles (13).

The reasons for these high NO_x values are: the concentration of mobile scurces in downtown Fairbanks and the strong atmospheric temperature inversions. The radiosonde soundings of temperature versus height above the Fairbanks International Airport, Table 2, column 8 show that there were only 3 days in February 1977 without a temperature inversion. The strongest inversion strength of 1°C per meter for the lowest 7 meters occurred on the 16th. Even though the radiosonde launch site is about 7.9 km (4.9 mi) from the Fairbanks post office, it is on the same flood plain and can therefore be expected to give some indication of the meteorology at the urban site. However, the strong anthroprogenic heat island over Fairbanks prevents direct extrapolation of airport data to the urban site. The heat island tends to allow some atmospheric mixing within the inversion layer (14).

The North Pole data follows the same trend as the Fairbanks data, i.e. the NO_x and CO peak on the same day. Even though North Pole is less than 1/5 the size of Fairbanks and is located 23 km (14 mi) south east of Fairbanks, it most probably sits under the same temperature inversion. And as in Fairbanks, mobile sources are the main generators of CO.

What is the ultimate fate of the reactive nitrogen and sulfur oxides? Sandberg et al. (15) suggest they usually precipitate from the atmosphere as salts. One of the major inorganic end products of NO_x is the nitrate ion (NO_3^-). For example, the nitrate ion would combine with any cation (M^+) to form the nitrate salt (MNO_3). Stoichiometrically, it would take approximately 0.0007 parts per million (ppm) of NO to form the 1.8 micrograms per cubic meter ($\mu g/m^3$) NO_3^- February 1977 average. Since the NO average amounts to 0.18 ppm, only about 0.4 percent of the NO makes it to the NO_3^- end product. A conversion of about 1 percent is achieved at the rural site if it is assumed all NO_3^- is of anthropogenic origin. However, the natural background NO_3^- may be high enough to make the rural site NO_x conversion appear higher than it really is.

Sulfur dioxide (SO_2) is likewise further oxidized to atmospheric sulfate ($SO_4^=$). Stoichiometric calculations show that the complete oxidation of 0.001 ppm of SO_2 should yield 4 $\mu g/m^3$ of $SO_4^=$. Since over 99 percent of the SO_2 readings were below the minimum detectable limit of 0.004 ppm, no conclusions can be drawn concerning SO_2 oxidation.

The very low SO_2 concentration indicates that little if any stack gases from the local coal burners was mixing into the lower atmospheric layer. When ice fog gets deep enough it has been observed to incorporate these power plant plumes.

During the two winter sampling periods, ice fog did not build up enough to entrap the plumes and cause ground level SO_2 concentration to increase.

Holty in 1972 (2) compared pollution levels with and without ice fog near downtown Fairbanks and found that the concentration of nitrogen oxides including nitrate plus nitrites and sulfates and lead were increased by a factor of two to three during ice fog. His SO_2 readings also increased by slightly more than 50 times.

During this (AERS) program there were only six days with ice fog during December 1977. The ice fog apparently did not increase the levels of the gaseous pollutants when compared to days adjacent to the ice fog period. However, six days is too short a time for comparison.

Since, in the Fairbanks area, automobiles and trucks are the major sources of NO_x and carbon monoxide (CO), it follows that there should be a close correlation between the two gases. The average ratio of CO to NO_x (CO/NO_x) from October through February of the second winter (urban) data was 34 for both the 24 hour average values and the one hour high values. The average linear correlation coefficients for this ratio (CO/NO_x:34/1) were 0.69 for the 24 hour average and 0.67 for the 1 hour high. These coefficients are high enough to state definitely that CO and NO_x are proportional to each other.

The CO and NO_x emissions for the most predominant stationary sources in Fairbanks - coal burners and domestic oil furnaces - is listed in EPA's AP-42(16). The emission ratio of CO to NO_x for both these fuels is less than 1. Environment Canada (17) measured CO and NO_x emissions in the range of -30 to +20°C from two 1975 automobiles. The ratio of CO to NO_x ranged from 41 at -30°C to 16 at 0°C. This emission ratio (CO/NO_x) range brackets the ambient ratio of 34, which would tend to indicate that the principal sources of NO_x must be internal combustion engines. If stationary sources were the major NO_x emitter, then the ambient ratio (CO/NO_x) would be about 1 or less.

PARTICULATES

The total suspended particulate measurements (TSP) that were performed during the first winter are listed in Table 4. Generally the particles appeared as soot on the Hi Vol filters. The exposed filters from the urban site had a characteristic odor of coal tar. Those from the rural site had little or no odor and at times had so few particles that a two day collection was necessary to get enough to weigh. The urban site particulates averaged 190 $\mu g/m^3$. And the rural site particulates averaged 19 $\mu g/m^3$. The urban site monthly averages were from 3 to 6 times the rural site particulate concentration. During breakup in April the road dust increased the urban site particulate levels by a factor of 10 over those in March.

The particulates data on Table 4 allows comparison between the total particulates, NO_3^- and $SO_4^=$. The rural site particulates have a higher fraction of NO_3^- and $SO_4^=$ than do the urban site particulates.

The lead (Pb) data is presented in Table 6. The AERS data is monthly average values. For the rural averages the Pb concentration ranged from 0.1 to 0.25 $\mu g/m^3$ and from 2.3 to 6 $\mu g/m^3$ for the AERS urban averages. The urban to rural ratios varied from 16 to 50 showing that the urban area has over 10 times the rural Pb concentration. The Fairbanks North Star Borough data is listed as daily averages. Their Pb data for Fairbanks is comparable to the old post office (AERS urban site) data even though the Borough's Hi Vol samplers were located from 2 to 4 m (6 to 12 ft) higher than the AERS sampler. Pb concentrations should be higher nearer the ground because the major source of Pb (automobile tailpipes) emits it at less than 1 m (3 ft) above street level and temperature inversions inhibit upward dispersion.

Pb is a substantial constituent of the total suspended particulates (TSP) measured in the populated air basin. The urban TSP contain more Pb than the rural TSP. For example, the AERS urban site TSP contained from 3.5 to 6.5 percent Pb, while the rural TSP contained only 1.4 to 2.2 percent Pb. The Borough (all urban) data also fits in with the AERS urban site data. The Pb content for the Borough data ranges from 1.9 to 6.8 percent of the TSP.

TABLE 6

FAIRBANKS AREA LEAD (Pb) DATA

Arctic Environmental Research Station Data

Date	Location	Pb µg/m³	Pb(100)/TSP
1976			
Nov.	Rural (R)	0.25	1.7
	Urban (U)	5.8	3.5
	Ratio (U/R)	(23)	
Dec.	Rural	0.11	2.0
	Urban	6.0	5.0
	Ratio	(55)	
1977			
Jan.	Rural	0.12	1.8
	Urban	6.0	6.5
	Ratio	(50)	
Feb.	Rural	0.18	2.2
	Urban	4.3	6.1
	Ratio	(24)	
Mar.	Rural	0.19	1.4
	Urban	2.3	4.3
	Ratio	(12)	

Fairbanks North Star Borough Data

Date	Location	Pb µg/m³	Pb(100)/TSP
12-9-77	Borough Bldg.	3.6	4.3
1-14-78	Borough Bldg.	4.6	6.8
1-20-78	Borough Bldg.	3.7	6.3
2-2-78	Borough Bldg.	4.7	5.2
2-7-78	Borough Bldg.	0.6	1.9
2-13-78	Borough Bldg.	4.2	6.8
2-19-78	Borough Bldg.	2.6	3.6
2-25-78	Borough Bldg.	1.0	2.7
11-8-75	Woolworths	6.5	3.5
11-14-78	Woolworths	4.7	5.3
11-20-78	Woolworths	12.3	6.3
11-26-78	Woolworths	1.0	1.9
2-12-76	Woolworths	6.8	3.2
2-18-77	Woolworths	2.1	3.3
2-24-76	Woolworths	1.8	3.0
11-3-77	Woolworths	1.9	2.6
11-9-77	Woolworths	3.8	3.7
11-15-77	Woolworths	1.5	3.6
12-3-77	North Pole School	2.8	5.0

NOTE: Pb(100)/TSP is the percent of the total suspended particles that is lead.

µg/m³ - micrograms per cubic meter at 76 cm of Hg and 25°C.

All of this atmospheric Pb must be of anthroprogenic origin since the natural background Pb concentration is less than 0.01 $\mu g/m^3$. Since there are no Pb related industries in the Fairbanks area, combustion of leaded gasoline is the major source of atmospheric Pb at all sites.

REACTIONS

Literature indicates that the SO_2 oxidation to SO_3 and on to $SO_4^=$ is enhanced by high temperatures (flue gas) and the presence of such catalysts as iron and vanadium in fly ash (7). On the other hand, research supported by the Electric Power Research Institute (18) indicated that the oxidation of SO_2 to $SO_4^=$ on High Volume filters (loaded with particulates) is accelerated by low temperature. The low temperature effects were not noticed, probably because the SO_2 levels were below instrument sensitivity.

NO is the major emitted form of NO_x, $(NO+NO_2)$ from combustion sources. When considering the nitrogen oxide data the extent of NO oxidation to NO_2 is determined by calculating the ratio of NO_2 to NO_x. That ratio (NO_2/NO_x) times 100 is the percentage NO oxidized to NO_2. For the urban winter data (exclusive of May) the percentage varied from 0 to 22 while it ranged from 43 to 85 percent for the rural data. Why was a larger fraction of the NO_x composed of NO_2 at the rural site, but composed of NO at the urban site? This was

probably due to the high concentration of NO and comparatively limited ozone (O_3) level at the urban site. Ozone, a very strong oxidant, is believed to be the main oxidizing agent for NO, via the following reaction: $NO + O_3 \rightarrow NO_2 + O_2$. In the polluted urban air, it is hypothesized that the reducing particulates such as soot and fly ash readily react with the O_3, reducing its levels to practically zero. Thus, because of the lack of oxidants such as O_3, the Fairbanks winter air can be considered to be rich in reducing agents. In contrast, photochemical smog, because it contains considerable O_3 and NO_2, is an oxidizing form of air pollution. The high ratio of NO to NO_2 at the urban site indicates that the oxidation rate (to NO_2) with atmospheric oxygen is probably insignificant.

The O_3 - NO reaction can best be illustrated by looking at the rural site (AERS roof) chart record for February 9, 1977, Figure 2. Beginning at 0900 hours the temperature, O_3 and NO_x are at their undisturbed (background) levels of -14°C, 0.028 ppm and 0.005 ppm. At 0930 hours it is assumed that an eddy draws some cooler, more polluted air up from the parking areas surrounding the AERS building. The air temperature at ground level is lower than on the roof - see airport data on Figure 2. This polluted air parcel is about 4°C cooler, and contains approximately 0.03 ppm NO which accounts for the low, <0.01 ppm O_3. The polluted (imported

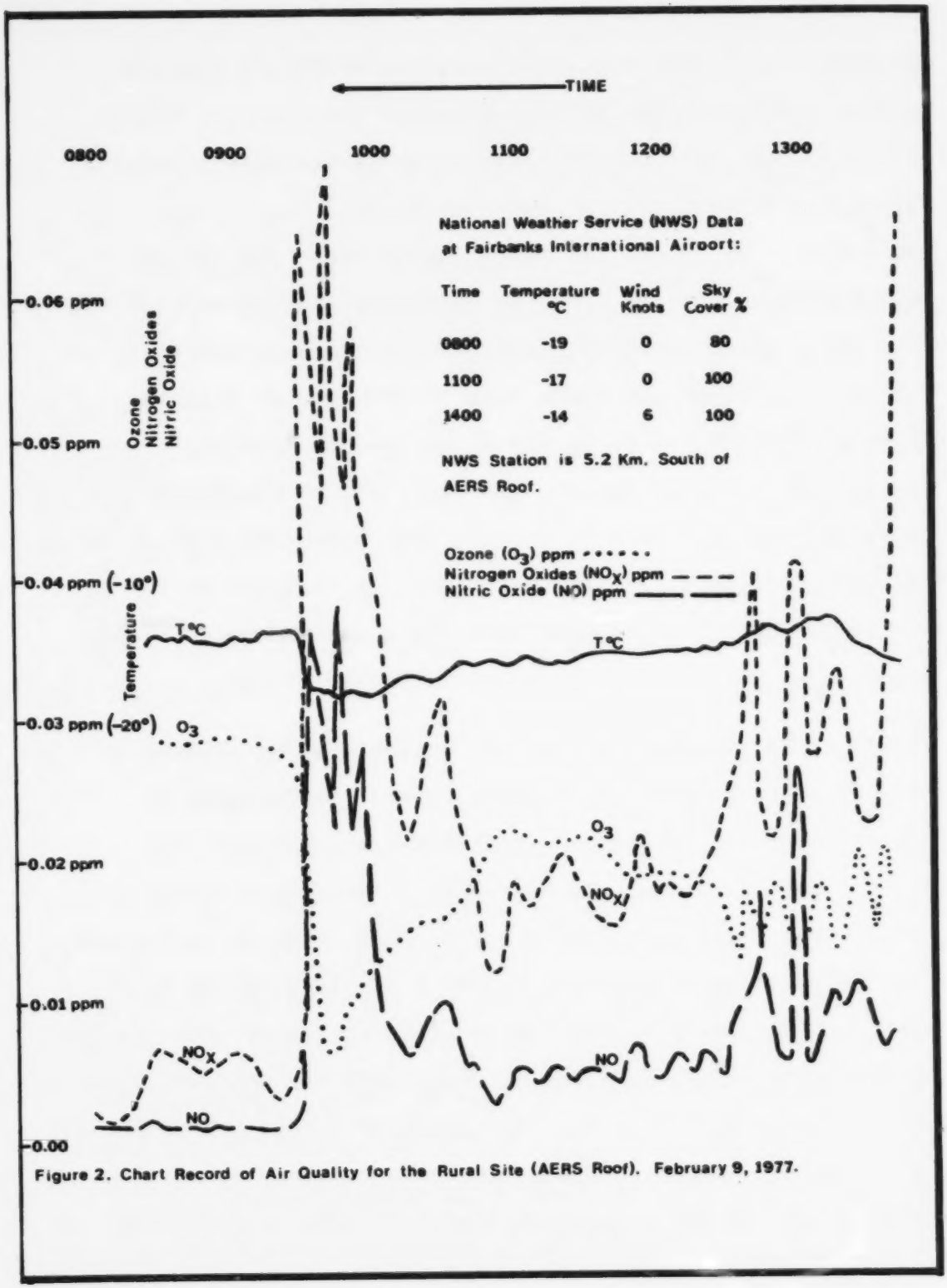

Figure 2. Chart Record of Air Quality for the Rural Site (AERS Roof). February 9, 1977.

parcel) is then slowly diluted with O_3 rich ambient air which dilutes the NO_x, raises the temperature, and causes a gradual rise in O_3. Total O_3 return to unpolluted levels (0.028 ppm) is prevented by the now higher NO (remaining for the polluted air parcel) which reduces it to O_2. From 1000 to about 1300 about every peak in the NO curve creates a corresponding flat or valley in the O_3 curve. The essence of Figure 2 is that natural ambient levels of O_3 cannot exist for any time period in concentrations of NO greater than about 0.03 ppm.

In more temperate climates, O_3 that is consumed by NO is replenished by photochemical action - the same photochemical action that is involved in photochemical smog. The prerequisites for photochemical smog are warm ($\geq$25°C) temperatures, insolation, and high concentrations of NO and reactive hydrocarbons (HC). Fortunately for Fairbanks, during most of the summer, winds and insolation inhibit formation of stable, long time (>24 hour) temperature inversions which would allow high concentrations of NO_x and HC. The remote possibility of photochemical smog in this northern city is discussed in Section 7.

When discussing the health effects of NO and NO_2, NO_2 is considered to be about five times as toxic as NO (7). Luckily, the low levels of O_3 in the downtown area limits formation of NO_2 from the emitted NO. However, when the NO

rich air drifts out of town and mixes with the cleaner O_3 rich air, it should be converted to the more toxic NO_2. A compensating factor to this apparently increasing toxicity is the accompanying dilution of the NO_2.

In summary, a most surprising finding was the NO - O_3 relationship. NO will readily react with O_3, but it is hypothesized that the dirty (high TSP) urban air limits the available O_3. Consequently, the NO to NO_x ratio was higher at the urban site than at the rural site. Because of a higher O_3 concentration in rural air the ratio (NO/NO_x) is expected to decrease downwind of the urban area. The ambient urban ratio of CO to NO_x was found to be about the same as the mobile source emission ratio. Therefore, the internal combustion engine is the major source of NO_x in Fairbanks. Also, the urban site atmosphere had winter average particulate levels exceeding 100 $\mu g/m^3$ which contained, on a monthly average, up to 6 $\mu g/m^3$ lead.

SECTION 6

INDOOR - OUTDOOR LEVELS

The short term indoor-outdoor air quality study at the new State Building yielded interesting results. Readings on the chart recorder for each CO analyzer were integrated to yield 1/2 hour CO averages for the major part of the working day (1000 to 1600 hours). Spanning the Ecolyzer (indoor CO) at 0900 and 1600 prohibited data collection before 1000 and after 1600 hours. The averages for January 16 through 18 and 22 through 25 are plotted on figure 3.

In all seven days, the indoor air heating ventilating unit (HVU) had about the same or greater level of CO than did the outside ambient air. It appears from the data for the 16th and 24th that, when the outside CO values averaged more than 8 ppm, the indoor CO values averaged more than 15 ppm. On the other hand, when both the indoor and outdoor CO values were low, as on the 17th and 18th, they were about the same. The combined maximum measurement inaccuracy of ±3 ppm CO would not affect the basic interpretation.

The building HVU was designed to take in fresh makeup air from the top of the building. Air at the higher elevation

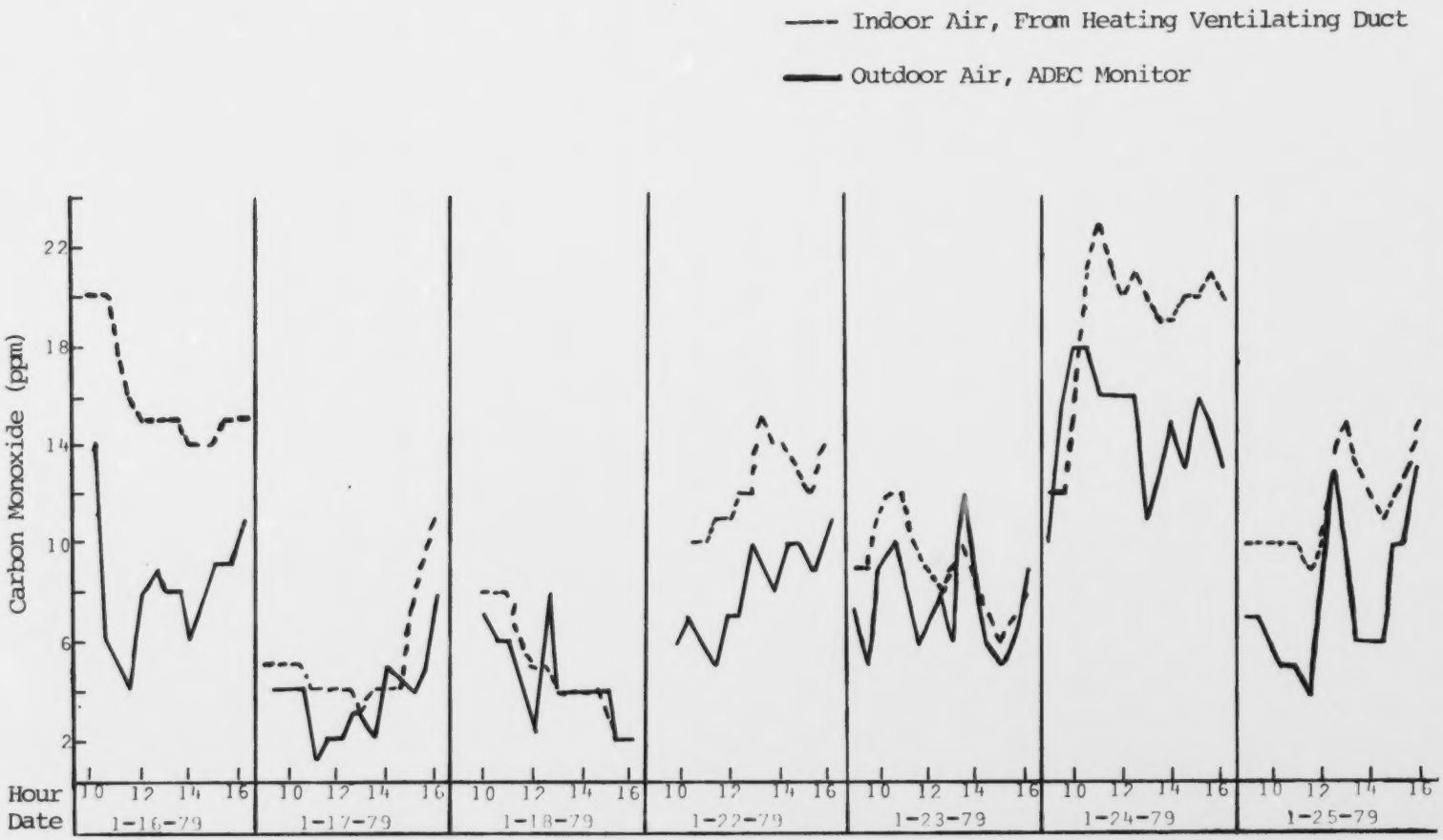

Figure 3. Carbon monoxide content of air (ppm, one-half hour average); at new State Building, Fairbanks, Alaska.

should contain less pollution than air at ground level because of the greater distance from automobile exhaust pipes. But at times, as shown in figure 3, the air in the building contains as much or more CO than outside ambient. There could be many reasons for this, but probably most of the CO is from automotive cold starts in the parking garage below the building. Located in the lowest level of the mechanical room is a large louvered fan assembly which exhausts into the garage when the building pressure exceeds atmospheric by a preset amount. The louvers do not seal tightly and during cold weather, considerable air from the garage leaks through into the mechanical room, which is also the return air plenum for the HVU. This leakage is probably enhanced by the chimney effect (hot air rises) of the building.

The NO_x values are one hour averages from 0800 to 1800 hours. The results are plotted in figures 4 and 5. The nitric oxide(NO) trend, figure 4,is considerably different from the CO trend. The outdoor NO levels are either higher or about the same as the indoor levels. This seems reasonable, because automobiles in the cold start or near idle mode emitt very little NO when compared to road speeds. Cold start or near idle mode emissions are the only type of emissions found in the garage.

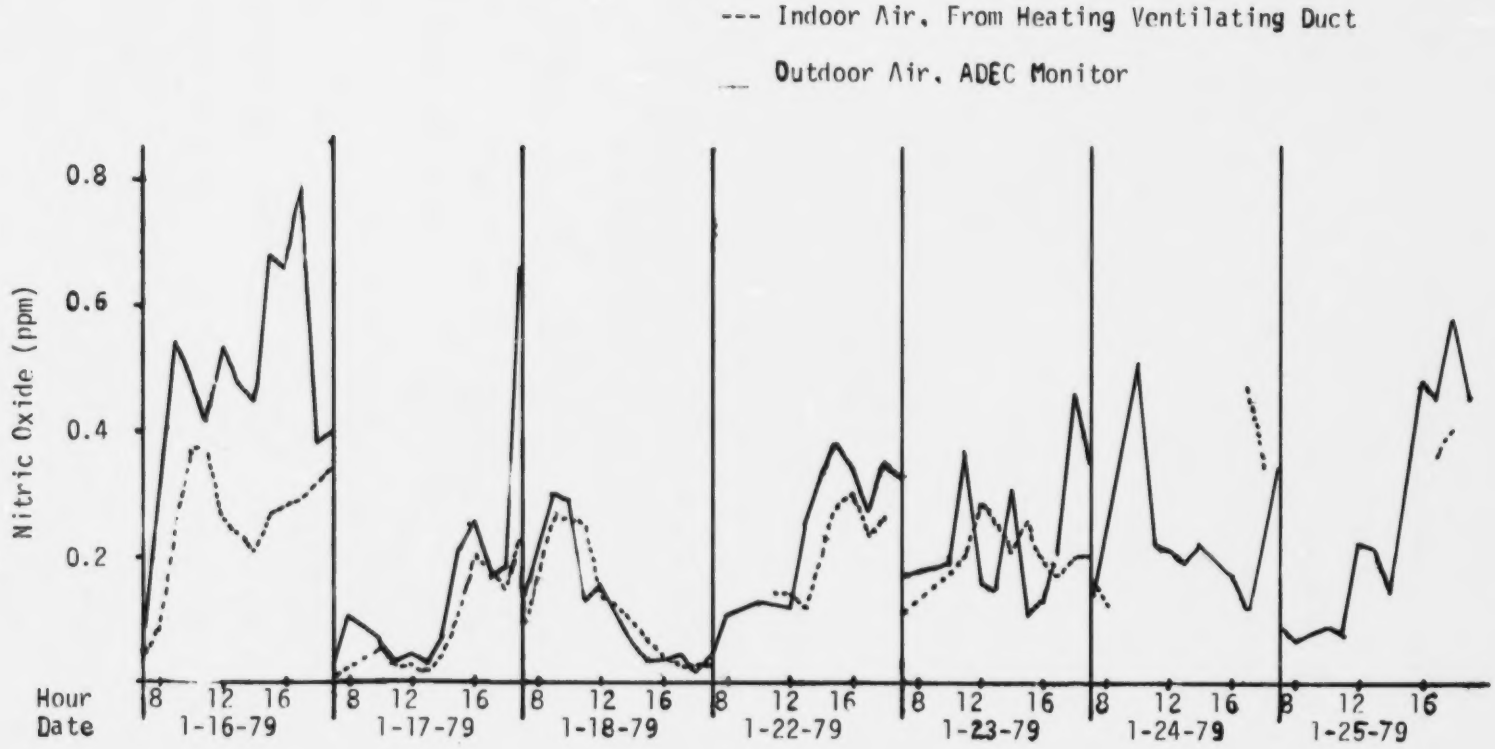

Figure 4. Nitric oxide content of air at new State Building, Fairbanks, Alaska.

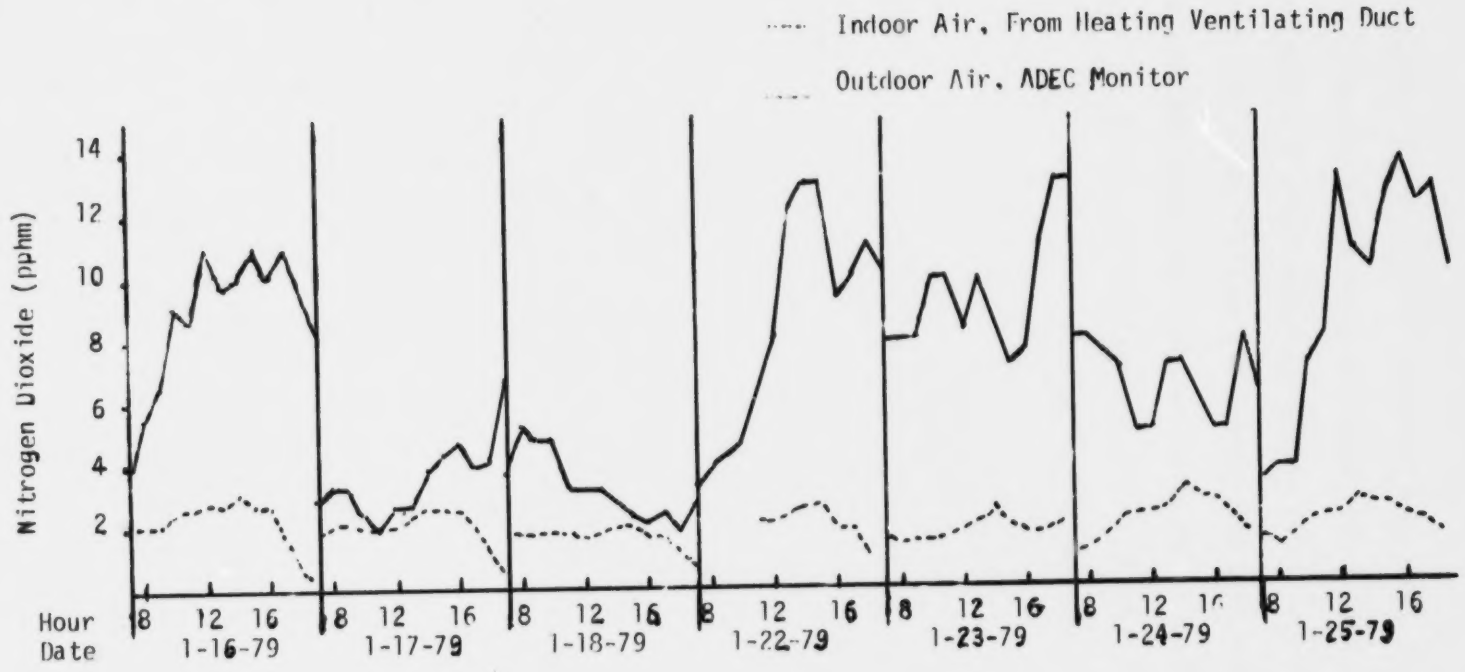

Figure 5. Nitrogen dioxide content of air at new State Building, Fairbanks, Alaska.

The nitrogen dioxide (NO_2) data, figure 5, follows the NO trend. The outdoor levels are higher than indoor levels. It is interesting to note that the outdoor to indoor ratios for NO_2 are generally higher than the same ratios for NO. This is as expected because the HVU air filters remove most of the O_3 from the intake air, and without O_3, the oxidation of indoor NO to NO_2 is inhibited.

SECTION 7

FAIRBANKS AIR QUALITY AND THE NATIONAL AIR QUALITY STANDARDS

WINTER AIR

The stagnant winter air over Fairbanks is not a problem peculiar to Fairbanks because long lasting winter temperature inversions are not uncommon to all cold regions. These inversions inhibit vertical dispersion. Horizontal dispersion is also inhibited because Fairbanks sits on a flood plain surrounded by hills on the north and west which block winter winds.

Mobile source emissions that accumulate in this stagnant air are the major source of air pollution in Fairbanks (19). The concern over these pollutants is their possible adverse effect on public health. This concern on a national level has resulted in the primary air quality standards.

AIR QUALITY STANDARDS

The primary air quality standards specify the maximum allowable ambient concentration of the more common air pollutants. These standards were first published by EPA in the

Federal Register on April 30, 1971 (20). The following is an excerpt from that publication:

"National primary ambient air quality standards are those which in the judgement of the Administrator (of EPA), based on the air quality criteria and allowing an adequate margin of safety, are requisite to protect the public health."

Those standards as promulgated in 1971 have, except for oxidants, remained basically unchanged to this date (February 1979), although there has been considerable debate as to the concentration of the pollutants where adverse health effects first begin to appear. A recent review by the Harvard School of Public Health, on the health effects of the regulated air pollutants (21) concludes (1) that the present primary standards seem adequate to protect public health and (2) until more data are available the standards should not be changed. A discussion of each pollutant's ambient concentration in relation to its regulated standard follows:

The EPA ambient air quality standards do not apply to air inside buildings. In non-domestic buildings, the Occupational Safety and Health Administration (OSHA) regulations apply.

CARBON MONOXIDE, PARTICULATES, AND ICE FOG

The ice fog, carbon monoxide (CO) and Total Suspended Particulate (TSP) problems are well known and will not be discussed here. An EPA summary on CO and TSP is published

in the Alaska Environmental Quality Profile (19). More up-to-date CO data has been summarized by the Fairbanks North Star Borough (22). A monitoring program for these pollutants is being carried out by the Fairbanks North Star Borough, Department of Environmental Services and by the Alaska Department of Environmental Conservation. The air quality standards for CO and TSP have been exceeded in Fairbanks in over 20 percent of all the daily readings (19). There is no air quality standard for ice fog. Efforts are being taken to reduce the levels of these three pollutants by the state, borough and city (Fairbanks) governments.

SULFUR DIOXIDE

The sulfur dioxide (SO_2) standard is 0.03 ppm maximum allowable concentration for an annual arithmetic mean and/or 0.14 ppm for a 24 hour average. During the sampling periods, over 90 percent of the urban site daily average readings were less than 0.005 ppm which is about 20 percent of the standard. Therefore, SO_2 was not found to be an air quality problem with the present emission sources. During long cold spells, ice fog can accumulate to a considerable depth. When ice fog builds up deep enough to entrap the taller power plant plumes, an increase in ambient SO_2 levels will result. But, based upon Holty's monitoring (2), that increased level is still not expected to exceed the SO_2 air quality standard.

NITROGEN OXIDES

The NO_2 standard is 0.05 ppm maximum allowable concentration, annual arithmetic mean. Only the urban site data for December 1976 has exceeded 0.05 ppm NO_2. And several other winter months have exceeded 0.02 ppm NO_2. This winter data coupled with the fact that air is more turbulent during the summer makes it doubtful that the annual mean would be exceeded in the near future.

In a recent report by the National Research Council (13), it is stated that based upon animal studies the biological toxicity of NO is much less than that of NO_2. Also, NO and NO_2 seldom occur separately so effects sometimes attributed to either may actually be a combined effect.

As of February 1979, there was no air quality standard for NO. But if there were, it would probably have come close to being exceeded during the observation periods. The reason for that conjecture depends on the relative toxicity ratio of 1 to 5 for NO to NO_2 as stated by Stern (7). Therefore, using the 1 to 5 ratio the 0.05 ppm standard for NO_2 would be comparable to 0.25 ppm NO. The urban monthly averages were more than 50 percent of that (0.25 ppm) for November through February - both winters. But because of unstable air during the summer, it is doubtful if a NO concentration of 0.25 ppm as an annual arithmetic mean would

be exceeded. However, effects of a short term exposure may be more significant. NO and NO_2 are respiratory irritants, the effect of which shows up with short term exposure to high concentrations. The necessity for a short term NO_2 standard is recognized by many health effects authorities (21). The maximum one hour integrated high value for NO was 1.8 ppm which is 7 times the extrapolated conjectural standard. Exposure to these peak values could result in much more adverse health effects than longer term exposures to lower concentrations.

MOBILE SOURCE EMISSION CONTROL EFFECTS

In Fairbanks mobile sources are major emitters of CO, NO, and lead (Pb). State implementation plans are being drafted to control CO. Some mobile source emission control efforts can be counterproductive. Techniques to reduce one pollutant can increase emissions of the others. Some CO control efforts may increase NO and Pb emissions. For example, use of leaner idle mixtures reduces automotive CO emissions, but it also increases NO emissions. In reducing the fuel to air ratio to lower CO from 1 to 1/2 percent an increase in exhaust NO of about 20 percent will result.

The present major automotive NO control technique, first widely used in 1973, depends upon exhaust gas recirculation. The exhaust gas recirculation system does not operate until

the vehicle speed exceeds about 25 mph. That average speed is not reached in the Fairbanks urban area; hence there is little NO control where it is really needed. But there is plenty of NO control in the rural areas where it is not as badly needed.

Emissions during automotive cold starts are the major source of the Fairbanks CO problem (23). Allowing a vehicle to continuously idle to eliminate the large CO output from a cold start will also increase the NO emissions. Pb emissions would also increase if leaded gasoline (regular or ethyl) is used.

LEAD

The recently adopted ambient air quality standard for Pb is 1.5 $\mu g/m^3$ maximum allowable three month average concentration (24). All five monthly average urban site samples during the first winter exceeded this value. The Pb levels nearer the sidewalk, closer to automobile exhaust pipes, are higher than those measured 3 m (9 ft) above the sidewalk (High Volume sampler inlet level). This is unfortunate because children breathe the air closer to the sidewalk. The standard was proposed to protect children since Pb is less toxic to adults.

OXIDANTS

The air quality standard for oxidants, measured as

ozone (O_3) has recently been raised to 0.12 ppm maximum allowable one hour concentration not to be exceeded more than once per year (25). This concentration was not exceeded in any of the winter measurements. However, during spring and summer in arctic regions, naturally occurring stratospheric downwelling and storm systems may cause the standard to be exceeded (9).

HYDROCARBONS

The HC standard is only a guide for air quality plans to achieve the oxidant (O_3) standard. It is not required to meet the HC standard if the O_3 standard has not been exceeded. The nonmethane hydrocarbon (HC) air quality standard is 0.24 ppm maximum three hour (6 to 9 a.m.) concentration. Gasoline engine operation that emits high concentrations of CO also emits high concentrations of HC. Therefore, the HC standard has by association with CO, probably been exceeded. This is of little health significance because most HC, at low concentrations (<10 ppm) are nontoxic.

Both the O_3 and HC standard were devised to control photochemical smog. Photochemical smog is the eye smarting form of air pollution for which the Los Angeles air basin is so famous. It has not yet been observed in most cold regions, so the oxidant and HC standard have at present little meaning.

PHOTOCHEMICAL SMOG

Whether or not photochemical smog could ever form in cold regions is a subject of debate. All that is needed is high NO_x and HC levels, warm air and strong sunshine. A study entitled, "The Effect of Latitude on the Potential for Formation of Photochemical Smog" (26) shows it to be possible during warm (>25°C), sunny, summer days with considerable HC and NO emissions.

Any petroleum related industrial development would probably be plants using HC for fuel and feedstock. These industries will increase the area wide emissions of SO_2, HC and NO. Also, the continued influx of automobiles into this developing area, which may be accelerated by industrial development, will increase HC and NO emissions. The resultant increased level of emissions increases the probability of a summer time photochemical air pollution problem in Fairbanks. This photochemical smog could have a much more adverse health effect than smoke from forest fires which are fairly common during dry summers. Smoke that inundates the urban areas from forest fires is irritating enough.

SECTION SUMMARY

To summarize this section, it can be said that most air pollution in Fairbanks is caused by internal combustion

(gasoline) engines. The ambient levels of CO, NO, and Pb are very high during the winter months. The CO standard and the proposed Pb standard have been exceeded routinely in the winter months. There is no NO standard. The oxidant and HC standard have, to date, little meaning because photochemical smog has not appeared in Fairbanks. However, future increases in HC and NO emissions will increase the potential for photochemical smog. SO_2 levels, primarily from stationary sources, were very low - less than 20 percent of the air quality standard.

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